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THE MAVROVO HYDROELECTRIC POWER PLANT SYSTEM

Engr Sava Kikic

The Mavrovo hydroelectric power plant system, which was started in 1947 and is still under construction, is located in the watershed between the Adriatic and Aegean Sea drainage areas. It is on the highway from Skoplje to Ohrid, 1,200 meters above sea level, in a ravine 15 kilometers long, 2 to 5 kilometers wide, surrounded on all sides by the wooded Vlajnica and Bistra mountain chains. A narrow gorge cuts through the mountain chain on the eastern side. The water from the Mavrovo ravine drains through the gorge into the Radika River valley, the Drim River, and finally the Adriatic Sea.

An earth dam, 80 meters high, one of the highest of this kind in Yugoslavia, is under construction here. It will prevent the drainage of water from the surrounding mountains into the Drim River and create a large artificial lake which will supply power and water to the Vardar valley. Considerable quantities of water from the Radika River and from the smaller Belicica, Jelovska, and Vrutocka rivers will also be stored in this lake.

A tunnel through the Vlajnica mountain chain is under construction opposite the lake. This tunnel will pipe water from the lake to the turbines installed underground at Vrutok. The water from the lake will also be utilized by the smaller installations on the edge of the Gostivar and Tetovo Plain at the foot of the Sar Mountains; then the same water will irrigate the Gostivar and Tetovo Plain, and the remaining water will be channeled to the Vardar bed to irrigate the other fields in the Vardar valley.

The Mavrovo hydroelectric power plant system is planned to be constructed in two stages. In the first stage, a year's accumulation of water will be stored in the lake. In the second stage, the lake will be enlarged to accommodate more than a year's accumulation.

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The first stage of construction involves an earth dam 48 meters high, with a volume of 550,000 cubic meters. The maximum headwater in the artificial lake will be at an elevation of 1,222 meters; the minimum headwater at an elevation of 1,207 meters; the headwater variation, 20 meters; the water volume below spillway level, 84 million cubic meters; the water volume above spillway level, 200 million cubic meters; and total volume, 284 million cubic meters. The following intake and discharge channels will be built (in meters):

	Tunnels	Canals	Siphons	Pipelines	Aqueducts	Total
Radika River	15,506	11,947	485	470	130	28,538
Belitsa "	-	10,250	130	-	-	10,380
Jelovska	350	10,100	-	-	-	10,450
Mavrovo - Vrutok	6,211	460	1,780	3,014	-	11,465
Total	22,067	32,757	2,395	3,484	130	60,833

The Vrben Hydroelectric Power Plant, one of the components of the Mavrovo system, will have four Francis turbines, each receiving 2 cubic meters of water per second, and utilizing a gradient of 193 meters. It will have a capacity of 12,500 kilowatts, and produce 44,800,000 kilowatt-hours of power /annually?/.

The Vrutok Hydroelectric Power Plant, another component of the Mavrovo system, will utilize a gradient of 550 meters. It will have four turbines, each receiving 8 cubic meters of water per second; it will have a capacity of 142,000 kilowatts, and produce 898 million kilowatt-hours of power annually.

The geological characteristics of the Mavrovo region are very diverse. The upper part, drained by the Radika River, is predominantly karst formations of limestone and fairly good chloride, quartz, or cerussite shales. The bottom and sides of the earth dam are cracked and broken diastase. The lower part, from the lake to the Vrutok Hydroelectric Power Plant, is marked by a large gorge, which runs along the edge of the artificial lake and cuts through the Vlajnica chain almost parallel to the Sar Mountain range along the edge of the Gostivar-Tetovo valley.

The secondary gorges, limestone formations, fractures, and the diverse composition of the mountain masses, varying from the poorest cerussite limestone to the best quartz and limestone, with frequent and sudden changes from one to the other, present a wide field for the application of various technical underground construction methods.

The state highway from Skoplje through Gostivar and Debar to Ohrid passes in the direct vicinity of the principal buildings of the lower section of the Mavrovo and Vrutok installations. However, 100 kilometers of new roads and approaches should be built; these would take into account the installations at Vrutok, the upgrade to the reservoir (a difference in elevation of about 600 meters), the diversion of the state highway from the dam because of flooding, a road around the lake, and a road through the difficult-to-approach faulted valley of the Radika River.

In addition to the new roads mentioned, and the 8-kilometer railroad spur from Gostivar to Vrutok, a 14-kilometer cableway is under construction. It goes from Vrutok (Hill 660) to the reservoir (Hill 1,240), along the path of the tunnel, through the deeply cut Dufska river valley (Hill 1,700) to Bogdevo and Nicpur in the Radika River valley.

Economical construction depends on using basic construction materials from local sources as much as possible: gravel or rock fragments, sand, and construction dirt. However, waterproof concrete linings for the tunnels, which are 3.20 meters in diameter, 6.1 kilometers long, and must withstand 3 to 7.5 atmospheres of pressure, cannot be made of rock fragments but will require good natural sand, which will have to be transported 80 to 100 kilometers. Stone quarries are to be opened near the individual buildings to supply over 200,000 cubic meters of material for concrete. A central stone quarry will be opened near the reservoir. This quarry will be equipped for the taking out, breaking, and separating of material according to pre-established ratios, so that the material transported by cableway will be selected and inspected before being transported. Laboratories to analyze soil, concrete, and cement will be at the building site. The strength of the underground stream flow and the preparation of concrete will be determined at research laboratories.

The dam, 48 meters high (54 meters in the second stage of construction), 6 meters wide, 190 meters long, 550,000 cubic meters in volume, is being built of clay soil. The side toward the water has a core wall of stone. The gradients vary between the limits of 1:2 up and 1:3 down. The discharge tunnel is parabolic in cross section.

The tunnel from the lake to the reservoir is about 6.1 meters long and 3.2 meters in diameter, and receives 32 cubic meters of water per second. The internal pressures in the first section of the tunnel which runs from the lake to the siphon are up to 4 kilograms per square centimeter. This section of the tunnel passes through about 500 meters of aluminiferous shale, then through broken cerussite shale, through graphite and chloride shale, and for 200 meters through limestone. This part of the tunnel is enclosed in ordinary grade 110 concrete 35 centimeters thick.

The second section of the tunnel from the siphon to the reservoir passes through graphite, chloride, and quartz shales, limestone, and slightly broken cerussite shale. The internal pressures vary from 6.3 to 7.5 kilograms per square centimeter. The selection of the tunnel lining is being studied so that this section of the tunnel, about 3 kilometers in length, will probably be lined with iron plate.

The crossing over the deep valley of the Dufska River is made by means of an 890-meter-long steel-lined syphon. Internal pressures vary from 4 kilograms per square centimeter at the beginning, 27 kilograms at the bottom, and 6 kilograms at the end. The maximum speed of the water is 7 meters per second. The siphon varies from 1,900 to 1,800 and 1,700 millimeters in diameter.

The reservoir is 80 meters deep and receives a maximum of 4.5 cubic meter of water per second.

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